Technology Development News

Exploring The State Of The Art For The State Of The Practice

WESTERN FEDERAL LANDS HIGHWAY DIVISION

MARCH **1998**

Drilled Shaft Installation at the Marble Creek Bridge Using Oscillatory Drilling Technology

by Tim Rogers, Bridge/Research/T2 Engineer, Washington Division

During the 1996 flood event in the Gifford Pinchot National Forest a plugged culvert caused 64,008 cubic meters (70,000 cubic yards) of roadway embankment to wash away at Marble Creek. According to Forest Service (FS) records, this was the third such occurrence in 22 years. Old logging debris in the drainage basin above the culvert apparently caused the blockage. Flood flows dislodged stumps and logs which blocked the pipe. To prevent future washouts at this location, the decision was made to remove the culvert and span the drainage with a bridge.

The Western Federal Lands Highway Division (WFLHD) is constructing a 95-meter (311-foot) 3-span, cast-in-place, concrete box girder bridge. The end abutments are founded on spread footings on rock and the two intermediate piers are single, fully-cased 2.4-meter (8-foot) diameter drilled shafts [24.4-meter (80-foot) and 12.2-meter (40-foot) shafts] socketed 1.2 meters (4 feet) into solid bedrock (grey andesite). The geotechnical exploration reported drilling through dense gravel, cobble, and boulders and observed boulders up to 2.4 meters (8 feet) in diameter in the eroded embankment. Written into the special provisions was the following advisory note:

> *"Boulders up to 6 to 8 feet occur within the materials at the east pier location. Nested pockets of boulders are also anticipated. The contractor should be aware that these conditions will have an impact on the construction of the drilled shafts and will likely greatly reduce the rate of drilling. The contractor should be prepared to remove boulders as part of the shaft excavation"*

Weaver Construction Company, LaGrande, Oregon was awarded the contract for $3.23 million. Weaver's bid amount for the drilled shafts was $3860 per linear foot (LF) and was the second lowest of the six bids submitted. The engineer's estimate for the drilled shafts was $2200 LF, and included the following sub-items:

- concrete and reinforcement
- excavation for drill access road and work pads
- excavation of rock at top of pier one
- select granular backfill
- controlled density backfill

Weaver Construction proposed to drill the shafts using an oscillating drill rig owned and operated by Malcolm Drilling, South San Francisco, California. The drilled shaft proposal was reviewed by WFLHD and Federal Lands Highway (FLH) Bridge Design and with minor modification was accepted as an alternative to the contract's permanently cased drilled shafts. This proposed drilled shaft installation method did not require permanent casing, therefore the bid amount was reduced by $12,000. Contained in Malcolm's submittal to the engineer was an installation plan for the drilled shafts.

Oscillator has "gripped" 8' diameter drill shaft. Shows lower ring, and the hydraulic lifters and opposing horizontal pistons.

In summary, the following basic operations are performed during installation:

- As the oscillatory drill advances the casing, the crane removes the spoils from the shaft with the use of a "hammer grab."
- As boulders are encountered, a rock chisel is used to break up the obstructions before the casing tip.
- When the casing tip is socketed 1.2 meters (4 feet) into rock, the bottom of the hole is cleaned and inspected for soundness.
- The crane places the reinforcement cage into the completed shaft.
- While concrete is being placed into the shaft, the oscillator retrieves the casing.

“Hammer Grab” recovery bucket with material from inside 8' diameter shaft.

Malcolm mobilized a 136-metric ton (150-ton) crane to the site to handle the oscillatory drill, drilling equipment, and casing, and a Leffer, German manufactured oscillatory drill with the following capacities:

- 7.11 Million Joule (5.25 Million Foot-Pound) Torque Capacity
- Downward Weight: 36 metric tons (40 tons)
- Extraction Force: 467 metric tons (515 tons)
- Drill Casing: 2.4 meters to 5 centimeters (8 feet to 2 inches) Outside Diameter, 2.1 meters to 22.9 centimeters (7 feet to 9 inches) Inside Diameter
- Rock and Boulder Breaking Tool: 4 metric tons (4.5 tons)

150 Ton Crane lifting the oscillator unit from lowboy.

This project gave WFLHD the opportunity to evaluate an oscillatory drilling technology that has been used in Hong Kong for the past 16 years but has had only one previous use on a United States transportation project. The new technology associated with the oscillating drill rig is its ability to cut through the soil as opposed to the hammering method done in conventional pile driving. In the oscillatory method, the soil is cut by fitting the tip of the casing with carbide teeth and then twisting (oscillating) it back and forth while the weight of the oscillating drill pushes the casing into the ground. The final product is a shaft of uniform cross-section from top to bottom. This type of drilling was especially beneficial at Marble Creek where 2.4-meter (8-foot) diameter piers were to be placed in soil containing boulders. The design also required piers of uniform diameter for their entire length. Traditional methods of drilling would have required the removal of the boulders as they were encountered which generally results in shafts of irregular cross-section and a longer installation time.

Malcolm's proposed drilling production rate for the shafts, presented at the preconstruction conference was 36.6 meters (120 total feet) of shaft in six working days or 6.1 meters (20 feet) of shaft per day. Placement of the reinforcement and concrete would require an additional day per shaft.

Based on the Federal Highway Administration (FHWA) Construction Inspector's daily reports, Malcolm's actual average production rate was 1.7 meters (5.5 feet) per day. The following production rates are a breakdown of Malcolm's progress in the materials encountered at the site:

- 0.3 to 0.6 meters (1-2 feet) per day in bedrock [grey andesite; 110,320 kPa (16,000 psi) unconfined compressive strength]
- 1.2 to 2.4 meters (4-8 feet) per day in material containing cobbles and boulders
- 5.5 to 7.3 meters (18-24 feet) a day in sandy, gravelly material

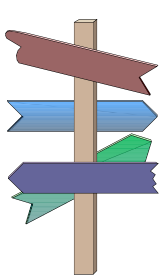
The contractor was required to perform quality control on the installation of the drilled shafts. The WFLHD was especially interested in Malcolm's ability to control the shaft's horizontal plan location, verticality, and profile. Malcolm used surveyed reference points to monitor the shaft's horizontal location and checked for vertical using a carpenter's level. To maintain a uniform 2.4-meter (8-foot) diameter profile, "glory hole drilling" (digging in front of the tip) was limited to a 15.2-centimeter (6-inch) depth.

When boulders were encountered, particular care had to be taken to insure that the casing stayed within the horizontal plan tolerance [+/- 7.6 centimeters (+/- 3 inches)]. As the tip of the casing encountered boulders or other obstructions, the casing would slide over the top of the obstruction and move the center of the casing to one side ("walking"). To stay within specification, the oscillator speed was slowed. The slower motion of the oscillator helped the carbide tips on the end of the casing grind through the boulder and avoid walking. During installation, 9.1 meters (30 feet) of casing was retracted and reset because it had deviated from the plan location by 15.2 centimeters (6 inches).

The shaft profile and diameter were verified by calculating the "yield" during the placement of the concrete. During construction both the volume of concrete placed in the shaft and the change in elevation of the concrete were monitored. Based on these observations the actual yields were between 101% and 106%. Thus the installed shafts had a uniform profile with a slightly larger diameter. The uniform shaft profile was especially critical in terms of predicting the seismic load distribution in accordance to its actual stiffness.

Though the actual production rates on this project were less than anticipated, the FHWA Project Engineer, Paul Rettinger, felt that the rates achieved in the soil conditions at Marble Creek were good. The oscillatory drilling technology has many advantages over the traditional methods of installing drilled shafts in soils containing obstructions. The main benefit of the oscillator technology is the ability to cut through obstructions and produce a uniform shaft profile. As with all drilled shaft installation methods, adequate Quality Assurance/Quality Control must be performed to insure a final product that is consistent with the project plans and specifications.

ROAD SIGNS



"None of us are responsible for all the things that happen to us, but we are responsible for the way we act when they do happen."

- Author Unknown

We wish to thank all the individuals who have contributed articles for previous newsletters. If you are aware of a new technology, (or a fresh spin on an old one) please jot down your ideas and submit them via e-mail to me at the address below. Or, if you have an aversion to writing, just donate 15 minutes of your time for an interview (either by phone or in person), and I'll format the information for you. You can then review the article for accuracy (via e-mail or hard copy) and upon publication, you'll become famous in a matter of days. Remember, although we cater to road-related technology, ANY new technology information is welcome.

Please send all submissions to Kristi Swisher - (360.696.7572). Be sure your name, title, and phone number are the way you want them to appear in the article. Articles are subject to editor/ layout approval and may be condensed if space is limited.

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